An Ultra-Light Weight Perching System for Sloped or Vertical Rough Surfaces on Mars

Principal Investigator: Arash Kalantari (347); Co-Investigators: Spencer Backus (347), Renaud Detry (KU Leuven), Angel Santamaria-Navarro (UPC Barcelona)

Program: FY21 R&TD Topics **Strategic Focus Area: Localization and Mobility**

Objectives

Developing an ultra light weight 10 percent of total system mass) perching mechanism and perception system that empowers a Martian flying vehicle to perch on steeply sloped or vertical walls to study and gather samples from otherwise inaccessible science targets

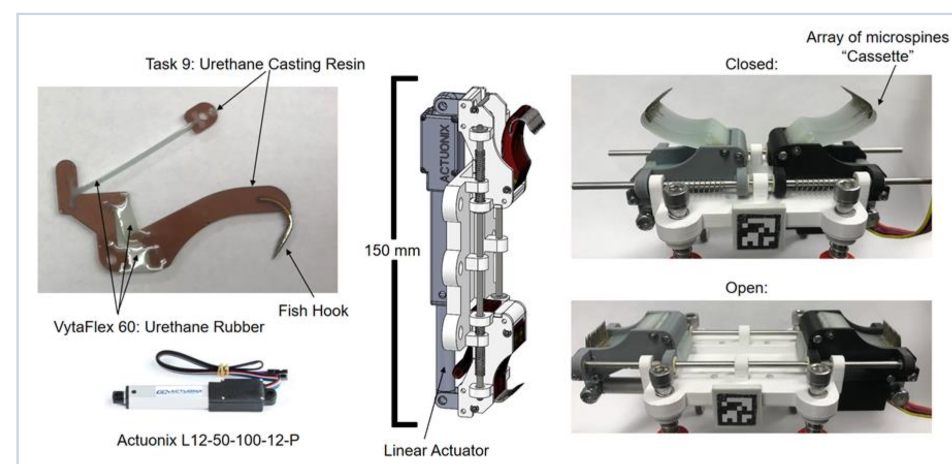
Background

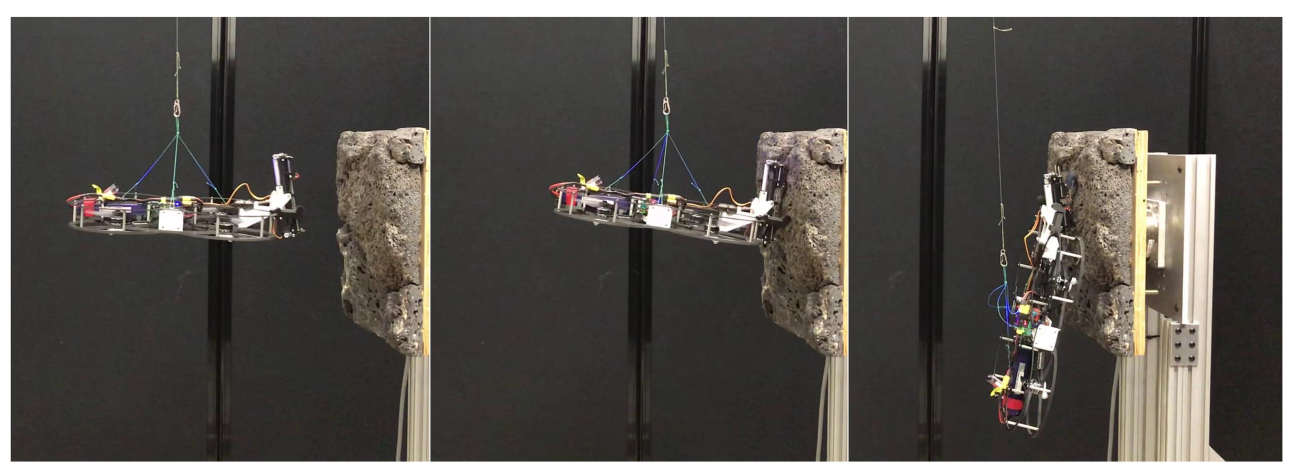
Steep slopes are often associated with geologically and astrobiologically interesting features, being sites of active modification (e g landslides/avalanches, slope streaks, RSL), exposed bedrock and/or ice, as yet unmodified young features (e g walls of fresh craters or polar pits that are actively expanding), and sites of flowing water

Approach and Results

Perching Gripper

Designed and prototyped a light weight perching gripper composed of two opposed sets of spines to resist forces in all directions. The gripper itself relies on elastic averaging to share loads between spines.



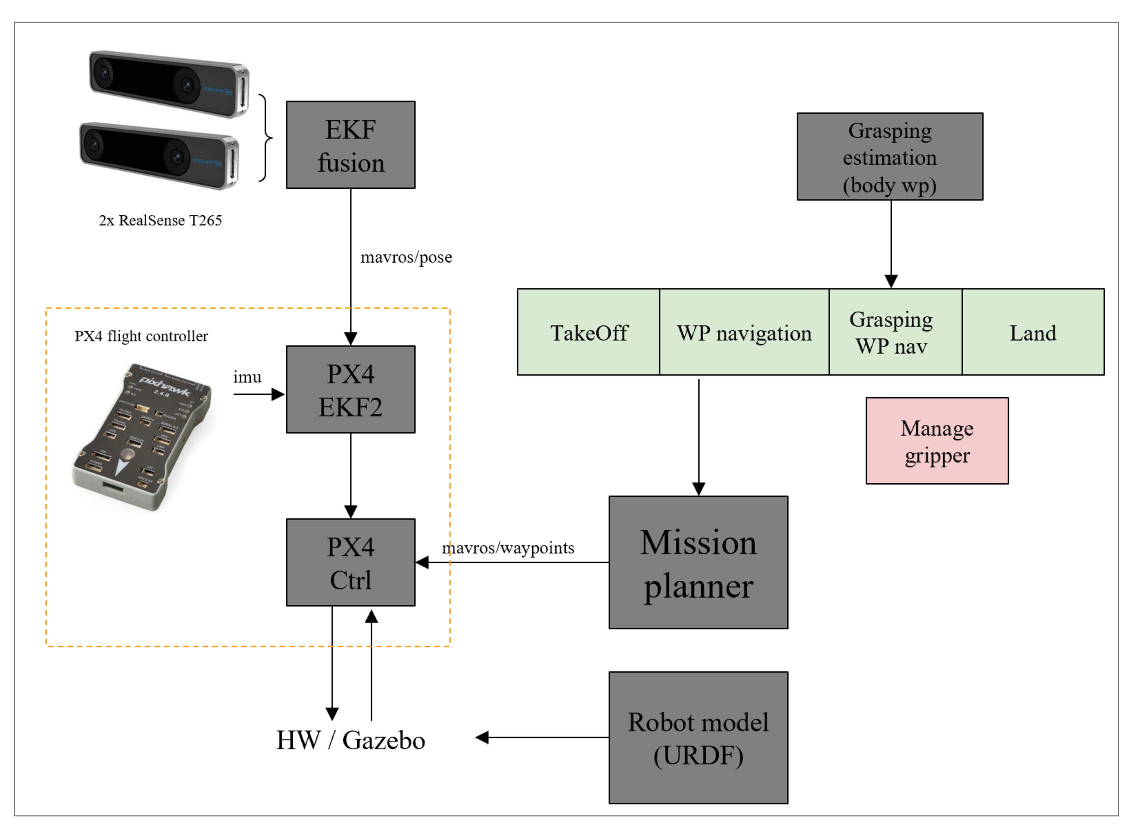


Perching Test

Tele-operated flight testing of the vehicle with integrated gripper demonstrated successful perching on vesicular basalt, a highly graspable rock type. The UAV perched successfully four times in a row, suggesting that the concept (outside the gripper itself) is suitably deterministic.

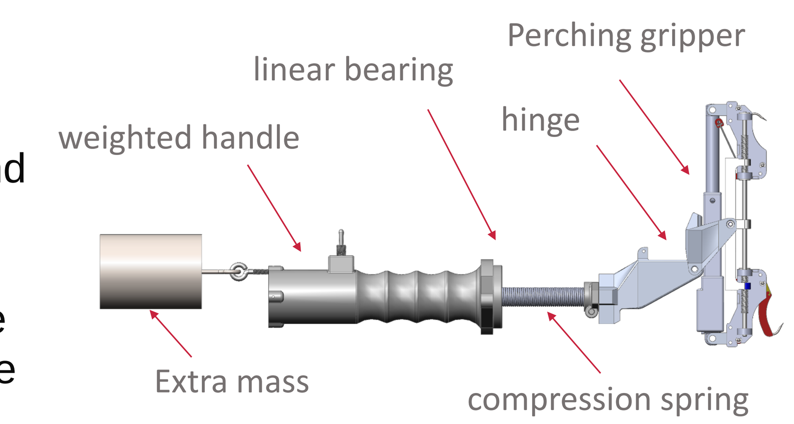
Navigation system

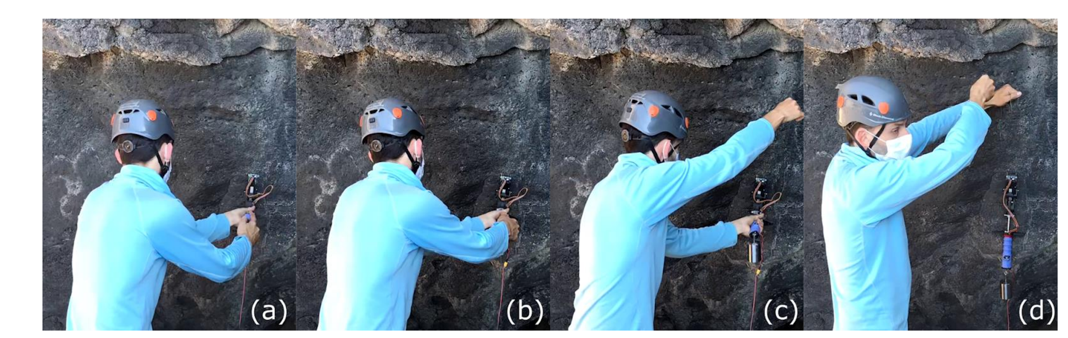
The goals is to guide the platform towards target perching point and bring gripper into contact with the surface. The platform takes off from a distance and flies toward the target point. The pose of the UAV during the flight is estimated by fusion of two Realsense T265 and on-board IMU using EKF implemented on the flight controller. Mission planner is a simple generic state's machine to manage behaviors of the system including take off, grasping point estimation, navigation towards goal, controlling the gripper, check grasp quality, and finally land. Each of these behaviors is programmed as a plugin and can be dynamically loaded (plugins) through the YAML file. The navigation system is completely simulated in Gazebo and results showed it can successfully guide the platform to the target perching locations.



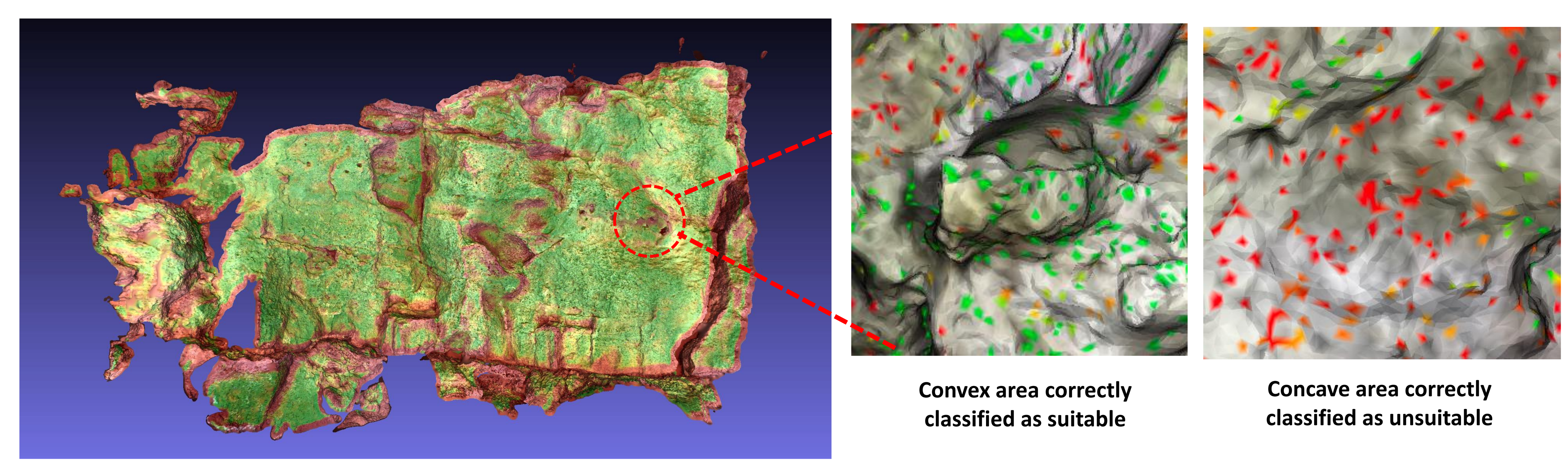
Perch-ability Algorithm

The gripper testing results suggest certain surface shapes (e.g., concavities) and textures (e.g., smooth surfaces) are adversarial and will often lead to a grasp failure. To maximize perching success, an image-based grasp model is developed, which enables measuring the perch-ability of arbitrary sites. The model takes an RGBD image as input, and it outputs a suitability score for a grasp that aims at the site shown at the center of the image. The rock data was obtained during a field trip at Pisgah, CA. Rock surface mesh was created with a structure-from-motion toolbox and a few dozen cell-phone images of relevant rock walls. Model is trained on expert-annotated data: manually outlined suitable or unsuitable areas on a high-quality rock mesh. Perch-ability was tested on 24 sites with a hand-held version of the perching gripper, and captured an RGBD image of each grasp site using Intel RealSense D435 RGBD camera. Grasp success was established via a dead mass representative of the copter. Grasp success/failure was recorded along with the captured RGBD image to automatically annotate the data during post processing.





Handheld operation of the gripper at Pisgah, CA: the gripper positioned, gripper engaged(b), the handle rotated downward (c), and handle released (d). The success of the grasp was verified by the gripper supporting 1.5 kg.



Convex area correctly classified as suitable **Concave area correctly classified as unsuitable**

Output of the perching model. Green and red dots show suitable and unsuitable sites, respectively.

Significance/Benefits to JPL and NASA

Martian environmental conditions severely limit rotorcraft flight times; the current Mars Helicopter can fly for only 90 seconds per charge. Consequently, the maximum ascending height of the Mars helicopter is limited to a few tens of meters. The proposed system will enable a mission to fly incrementally up (or down/across) the walls of e.g. Valles Marineris (7km depth) through sequences of flying and perching, even with short individual flights. Additionally, such a flying system could recharge its batteries while perched using solar panels, enabling long transects up or across canyon walls and crater outcrops. A potential nearer-term infusion pathway is for a future Mars lander or rover to detect an area of interest near the primary mission site on a steeply sloped or vertical surface, deploy the flying system to perch and investigate the target, or to extract and return samples back to the lander/rover. Moreover, the proposed mechanism can be adapted by other flying systems (free-flyers, CubeSats, etc.) to perch onto surface of comets, asteroids, the Moon or Phobos to study the surface, extract samples, and recharge batteries.

National Aeronautics and Space Administration

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

www.nasa.gov

PI/Task Mgr Contact
Email: arash.kalantari@jpl.nasa.gov

Clearance Number:
RPC/JPL Task Number: R19118